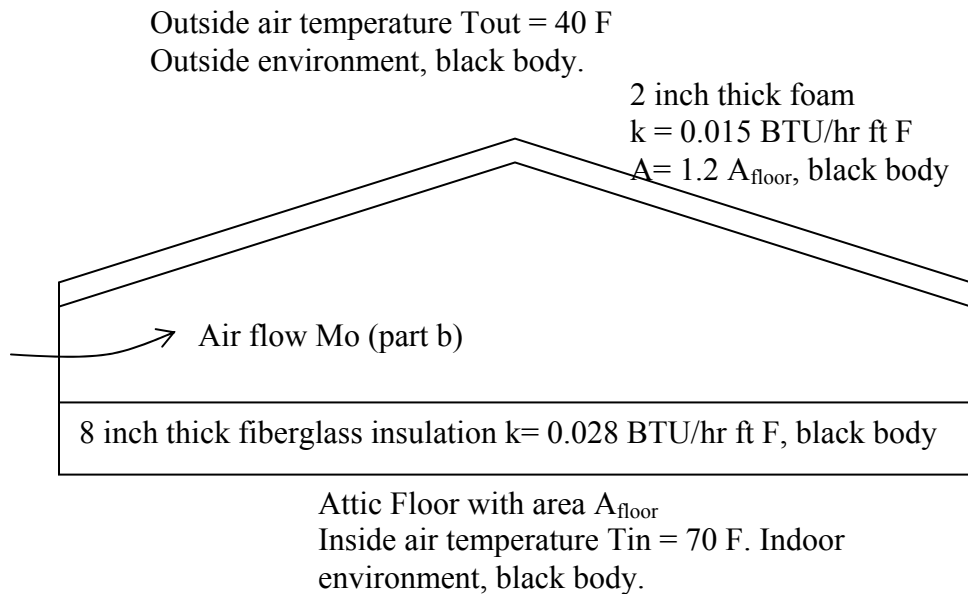


4.42 Final
December 16, 2003
Open Book

1) (25) The attic of a single family house has 8 inches of fiberglass insulation ($k = 0.028$ BTU/hr ft F) on the attic floor. The homeowner has added 2 inches of foam insulation ($k = 0.015$ Btu/he ft F) on the underside of the roof. The outside air temperature is 40 F and the temperature of the occupied space beneath the attic floor is 70 F. The outside environment and the indoor environment can be looked as black body, which has same temperature as the outside and inside air temperature respectively. The foam and fiberglass insulation also can be viewed as black body. Assume that the air in the attic is at a uniform temperature.

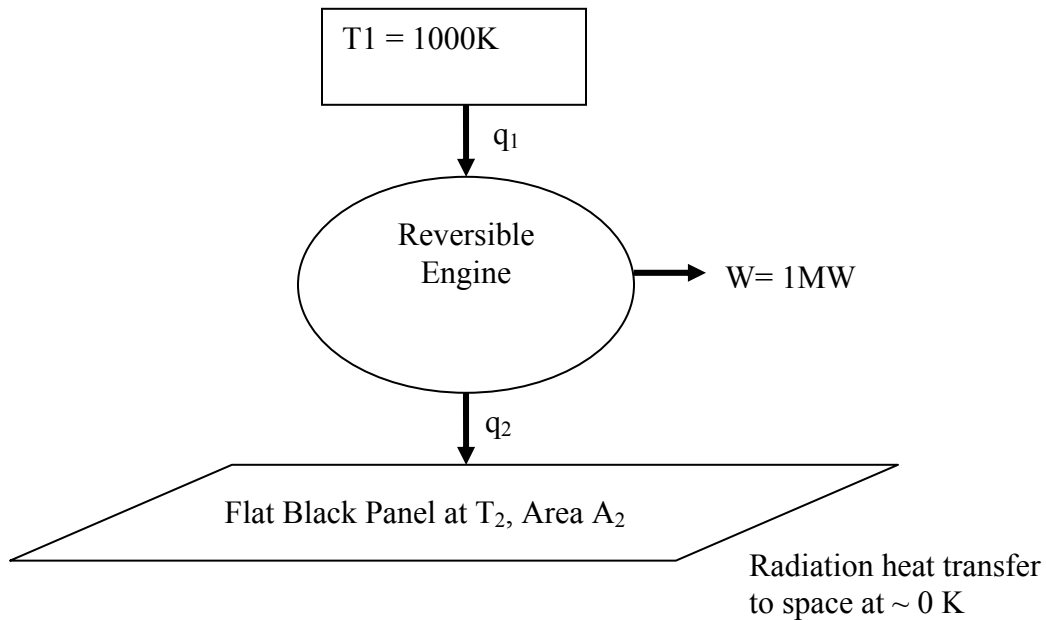
a) If the attic is sealed so that no outside air can leak in, set up but do not solve, the electrical analogy for the heat transfer from the interior of the home to the outside air through the attic. Estimate the numerical value of each resistance element in the electrical analogy in terms of the attic floor area, A_{floor} .

b) If the outside air flows into the attic at a flow rate of M_o , set up, but do not solve, the equations that will allow prediction of the attic air temperature. Clearly identify the definition of all terms in your equations. Assume the air in the attic is well mixed at a uniform temperature.



2) (25) After he has conquered most of the architectural challenges throughout the world, it might be appropriate for the Stata Center architect to help NASA design the future Space based Stata Center. As usual, the design will be over the top requiring substantial electrical power for many years of operation in space. It is proposed to use a reversible engine that receives heat from an isotope heat source. The isotope provides heat to the engine at 1000K, T_1 . On the low temperature side of the engine, heat is rejected by radiation heat transfer to outer space (effectively at 0 K) by use of a black flat panel “radiator” at temperature T_2 . Only one side of the panel acts as the radiator. Most of the power plant system weight is due to the radiator panel, whose weight varies linearly with its area A_2 . The engine must produce a continuous power of 1 MW. Note, in this problem the large temperature difference between T_2 and outer space precludes the use of the linearized form of the radiation heat transfer.

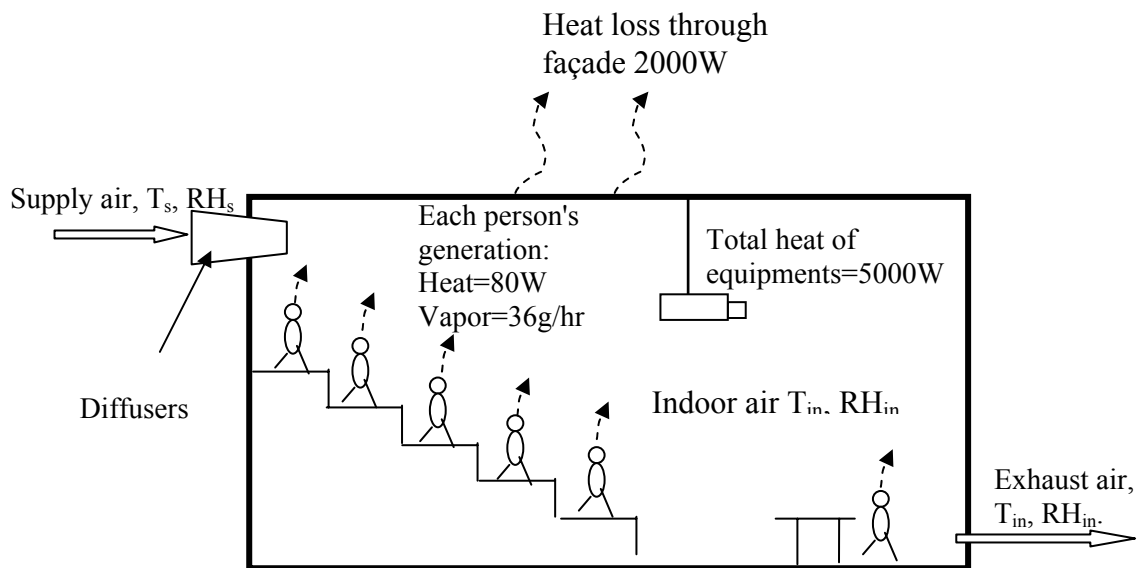
- If T_2 is set at 300 K how large an area A_2 is required for the system to generate 1 MW of power?
- Consider different possible values for T_2 . Sketch a graph showing how q_2 , the heat rejected by radiator, varies with T_2 for a fixed power output and fixed T_1 . Now sketch the ratio of A_2/q_2 as it varies with T_2 .
- Indicate graphically how you would use the results of part b to find the value of T_2 that minimizes the radiator area A_2 for a fixed power output and a fixed value of the upper temperature T_1 .



3) (25) In winter, a MIT conference room has 100 people gathered together for a meeting. The current indoor air temperature is $T_{in}=28^{\circ}\text{C}$, $\text{RH}_{in}=90\%$. Because there are heat sources generated from people and equipment in the room, this conference room may become hotter and hotter if we don't supply cooling air into it.

(a). Some people suggest supplying outside air directly into the space via diffusers without any heating or moisture addition. The current outside air temperature is 0°C , $\text{RH}=80\%$. Is this strategy feasible? If yes, please give its advantages. What are its drawbacks, and how would you improve it?

(b). The indoor air temperature becomes $T_{in}=25^{\circ}\text{C}$, $\text{RH}_{in}=60\%$ after one hour. In order to keep this condition steady, we need to supply a constant flow rate of air into this conference room. If the heat generated by each person is 80W , the vapor generated by each person is 180g/hr , the heat generated by equipments is 5000W , the heat loss through the room's façade is 2000W , how much air should be supplied into the room if we keep the supply air temperature as $T_s=18^{\circ}\text{C}$? What should the relative humidity of the supply air be to maintain the room RH_{in} at 60% ? Assume that the exhaust air has same state as indoor air ($T_{in}=25^{\circ}\text{C}$, $\text{RH}_{in}=60\%$). Assume that there isn't any air leakage or other heat transfer into the room. Specific heat of air, $C_p=1.01\text{kJ/kg}\cdot^{\circ}\text{C}$, is constant between temperature 0°C to 30°C .



4) (25) In a large air conditioner the refrigerant in the condenser transfers heat to cooling water (see the picture). The cooling water flows to a cooling tower where it is sprayed as very small water drops into the top of the cooling tower. Ambient air will be induced into the cooling tower from the bottom by a fan installed on the top of the cooling tower. There will be some water evaporation from the droplets and there will also be heat transfer between the air and water in the cooling tower. Then the cooled water will be returned to the air conditioner's condenser.

We assume:

- a. The water pipe between the condenser and cooling tower is insulated so that there isn't any heat exchange with the outside environment.
- b. The cooling tower façade is insulated very well and there isn't any heat exchange with outside environment.
- c. The condenser is insulated so well that there isn't any heat exchange between the condenser and ambient environment. That is to say, the refrigerant only exchanges heat with water in the condenser.

We know:

- a. The water temperature before entering the cooling tower is $T_{w,1}=35^{\circ}\text{C}$, and the water flow rate is 60kg/s . Specific heat of water $C_v=4.18\text{kJ/kg}\cdot^{\circ}\text{C}$.
- b. The air temperature before entering the cooling tower is $T_{a,1}=25^{\circ}\text{C}$, $\text{RH}=60\%$, and its leaving temperature $T_{a,2}=28^{\circ}\text{C}$, $\text{RH}=100\%$. The flow rate of the air is 25kg/s .
- c. The COP of the air conditioner is 3.0.

Questions:

- a. What is the rate of water evaporation in the cooling tower (kg/s)?
- b. Calculate the value of the temperature ($T_{w,2}$) of the water returning from the cooling tower, before it enters the condenser.
- c. If the air conditioner is used in steady state to cool a room space, what is the rate of cooling (Q_c)?

